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NMR lineshape in anisotropic superconductors

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Abstract

It is shown that the NMR lineshape strongly differs for various angles between normal to the surface of the superconductor and the external magnetic field direction. Thus, the surface effects drastically change the conclusions concerning the vortex lattice and parameters of the superconductor that are usually extracted from the NMR line shape. The NMR probing in the inclined magnetic fields will provide more detailed information about the parameters of the superconductor, especially in strongly anisotropic high-T_c superconductors. © 2000 Elsevier Science B.V. All rights reserved.

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The nuclear magnetic resonance (NMR) is well known as a useful tool for the investigation of high-T_c superconductors properties. To interpret the NMR lineshape the following three important circumstances are necessary to take into account: the first, homogeneous width of the line, the second, inhomogeneity of a local magnetic field $\boldsymbol{h}(\boldsymbol{r})$ in a superconductor, the third, peculiarities of a penetration of a microwave magnetic field in a superconductor. Because the AC electromagnetic field penetrates into a superconductor on depth of the order of the magnetic penetration depth λ [1] only, it is necessary to take into account the inhomogeneity of the magnetic field $\boldsymbol{h}(\boldsymbol{r})$ in a narrow area near the superconductor surface. However, the inhomogeneity of the magnetic field in a vortex lattice near the surface of the type-II superconductor considerably differs from the $\boldsymbol{h}(\boldsymbol{r})$ inhomogeneity in a bulk superconductor [2].

In Ref. [3], the perpendicular orientation of the external homogeneous magnetic field $\boldsymbol{H}$ with respect to the superconductor surface has been considered. If the surface effects are taken into account, the conclusions about the vortex lattice and parameters of the superconductor based on the analysis of the NMR lineshape drastically change [4]. As high-T_c superconductors are strongly anisotropic, it is interesting to consider the changes of the line shape parameters in the inclined external magnetic field with respect to the superconductor surface. In the present work, the NMR line shape is considered in view of the surface effects according to various angles θ between the normal to the superconductor surface and the direction of the external magnetic field $\boldsymbol{H}$.

In anisotropic superconductors with the Ginzburg–Landau parameter $\kappa \gg 1$, the local field $\boldsymbol{h}(\boldsymbol{r})$ obeys the generalized Londons equation with a mass tensor m_{ik}. We solved this equation and determined $\boldsymbol{h}(\boldsymbol{r})$ of a vortex lattice for the half-space occupied by the uniaxial anisotropic superconductor in the inclined external magnetic field (see also Ref. [5]). Then we constructed a distribution functions of $\boldsymbol{h}(\boldsymbol{r})$ within primitive cell of the flux line lattice at various depths from the superconductor surface. We have carried out calculations of the absorption intensity assuming that AC magnetic field exponentially decreases with the depth from the superconductor surface and every resonant nuclear spin has its own resonant curve of the Lorentz form with width δ. A scheme of calculations is the same as in Ref. [3].

The NMR lines of the anisotropic superconductor with $\delta = 0.01$ and the anisotropy parameter $\Gamma = 25$ for the various angles θ are given in the Fig. 1 ($\Gamma = m_3/m_1$; $m_1 = m_2$, m_3 are the principal values of m_{ik}). The NMR absorption intensity $P(H)$ is plotted versus a parameter

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